Lessons from the Deep:
Exploring the Gulf of Mexico's Deep-Sea Ecosystems
Education Materials Collection

Image captions/credits on Page 2.

lesson plan

How Diverse is That?

(adapted from the Expedition to the Deep Slope 2006)

Focus
Quantifying biological diversity

Grade Level
9-12 (Life Science)

Focus Question
What do ecologists mean when they say a biological community is "diverse?"

Learning Objectives
- Students will be able to discuss the meaning of "biological diversity," and will be able to compare and contrast the concepts of "variety" and "relative abundance" as they relate to biological diversity.

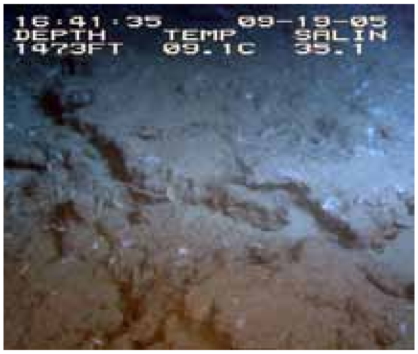
- Given abundance and distribution data of species in two communities, students will be able to calculate an appropriate numeric indicator that describes the biological diversity of these communities.

Materials
- Copies of *Species Distribution in Seep and Non-Seep Areas at Two Sites on the California Slope*, one copy for each student group

Audio/Visual Materials
- Overhead projector and transparencies, or marker board

Teaching Time
One or two 45-minute class periods, plus time for group research

Seating Arrangement
Groups of 4-6 students



Areas of active, if subdued, hydrocarbon seeps are notably devoid of large sessile invertebrates. A fluffy gray biofilm coats the underlying rock, dotted with small white patches of the cold-seep-associated bacteria *Beggatoia*. Image courtesy Ken Sulak USGS 2004-2006 *Lophelia* program Chief Scientist.
http://fl.biology.usgs.gov/images/pictures/CHEMO_SEEP_BIOTOPE.jpg

This group of very old tubeworms (*Lamellibrachia luymesi* and *Seepiophila jonesi*) live on the same piece of carbonate rock as large colonies of the gorgonian *Callogorgia Americana*. Note the brittle stars and a galatheid crab crawling on the gorgonians. Image courtesy Derk Bergquist.
http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/signature_600.html

Images from Page 1 top to bottom:

A close-up mussel aggregation with *Chirodota heheva* sea cucumbers. Image courtesy of Expedition to the Deep Slope 2007.
http://oceanexplorer.noaa.gov/explorations/07mexico/logs/july3/media/cuke_600.html

A CTD rosette being recovered at the end of a cast. Note that the stoppers on the sample bottles are all closed. Image courtesy of INSPIRE: Chile Margin 2010.
http://oceanexplorer.noaa.gov/explorations/10chile/logs/summary/media/2summary.html

A methane hydrate mound on the seafloor; bubbles show that methane is continuously leaking out of features like this. If bottom waters warmed, this entire feature may be destabilized and leak methane at a higher rate.
http://oceanexplorer.noaa.gov/explorations/10chile/background/methane/media/methane4.html

Lophelia pertusa create habitat for a number of other species at a site in Green Canyon. Image courtesy of Chuck Fisher.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

Maximum Number of Students

30

Key Words

Cold seeps
Methane hydrate
Clathrate
Diversity
Diversity index
Species richness
Species evenness
Gulf of Mexico

Background Information

Deepwater ecosystems in the Gulf of Mexico are often associated with rocky substrates or "hardgrounds." Most of these hard bottom areas are found in locations called cold seeps where hydrocarbons are seeping through the seafloor. Microorganisms are the connection between hardgrounds and cold seeps. When microorganisms consume hydrocarbons under anaerobic conditions, they produce bicarbonate which reacts with calcium and magnesium ions in the water and precipitates as carbonate rock. Two types of ecosystems are typically associated with deepwater hardgrounds in the Gulf of Mexico: chemosynthetic communities and deep-sea coral communities. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, so the presence of these ecosystems may indicate potential sites for exploratory drilling and possible development of offshore oil wells. At the same time, these are unique ecosystems that may be important in other ways as well.

Deepwater chemosynthetic communities are fundamentally different from other biological systems, and there are many unanswered questions about the individual species and interactions between species found in these communities. These species include some of the most primitive living organisms (Archaea) that some scientists believe may have been the first life forms on Earth. Many species are new to science, and may prove to be important sources of unique drugs for the treatment of human diseases. Because their potential importance is not yet known, it is critical to protect these systems from adverse impacts caused by human activities.

Ironically, one of the most likely sources of such impacts is the same activity that led to the discovery of these systems in the first place: exploration and development of petroleum resources. An essential part of strategies to protect deepwater ecosystems requires new ways to locate deepwater biological communities, evaluate their

Viosca Knoll is an elevated salt dome with dormant and active cold seeps. Where hydrocarbons are actively escaping from the substrate, dense clusters of tightly entwined vestimentiferan tubeworms grow. As the submersible approaches, it disturbs a blackbelly rosefish (*Helicolenus dactylopterus*), and a conger eel (*Conger oceanicus*). Image courtesy Ken Sulak USGS 2004-2006 *Lophelia* program Chief Scientist.
http://fl.biology.usgs.gov/images/pictures/CHEMO_TUBE-WORM_BUSH.jpg

These methane mussels (*Bathymodiolus childressi*) live at the edge of Brine Pool NR1 at 650 m depth in the Gulf of Mexico. The pool of brine in the foreground is nearly four times as salty as seawater and is so dense that the submersible can float on the pool to take pictures such as this. Image courtesy Stephane Hourdez.
http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/mussels_600.html

Lophelia pertusa coral, with opened polyps, attached to an authigenic carbonate rock. Seep-dependent tubeworms are visible behind the coral. Image courtesy of, *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs and Wrecks.
http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/aug25/media/lophelia_insitu_.html

sensitivity to impacts from human activities, and understand more about the ecological relationships of organisms that inhabit these communities.

One of the ways scientists describe and compare biological communities is based on the abundance of species and individuals within a specific area. Two measurements are frequently used:

- Species Diversity (S) - the number of species in the environment; and
- Species Evenness (or equitability) - a measure of how evenly individuals are distributed among these species.

Evenness is greatest when species are equally abundant. The simplest measure of species diversity is the number of species present in an environment. This is called species richness. But there is more to diversity than just the number of species in an environment. A community that has more or less equal numbers of individuals within the species present is usually thought of as more diverse than a community that is dominated by one species. For example, samples from two separate communities might each contain the same seven species, with distribution of individuals as shown in Table 1:

Table 1

Species	Number of Individuals	
	Community 1	Community 2
Species a	44	8
Species b	2	8
Species c	2	8
Species d	2	8
Species e	2	8
Species f	2	8
Species g	2	8
Total	56	56

Our notion of what "diversity" means leads us to consider Community 2 as more diverse than Community 1, even though they both have the same number of species and total individuals.

Because of the importance of both species evenness and species richness to our idea of diversity, some measures of diversity include a way of including both concepts. One commonly used measure of species diversity that includes proportions of individuals is the Shannon-Weaver information function which is:

$$H = -\Sigma p_i \ln p_i$$

Where:

H is the diversity index
ln is the natural logarithm
i is an index number for each species present in a sample
$\mathbf{p_i}$ is the number of individuals within a species (ni) divided by the total number of individuals (N) present in the entire sample

To calculate the diversity index H, you multiply the proportion (pi) of each species in the sample times the natural log of that same value (ln pi), then sum (Σ) the values for each species, and finally multiply by -1.

Table 2 illustrates the calculation:

Table 2

	Number of Individuals	Proportion (p_i)	$\ln(p_i)$	$p_i \ln(p_i)$
Species a	3	3÷47 = 0.064	-2.749	0.064 • -2.749 = -.176
Species b	5	5÷47 = 0.106	-2.244	0.106 • -2.244 = -.238
Species c	10	10÷47 = 0.213	-1.546	0.213 • -1.546 = -.329
Species d	6	6÷47 = 0.128	-2.056	0.128 • -2.056 = -.263
Species e	12	12÷47 = 0.255	-1.366	0.255 • -1.366 = -.348
Species f	7	7÷47 = 0.149	-1.904	0.149 • -1.904 = -.284
Species g	4	4÷47 = 0.085	-2.465	0.085 • -2.465 = -.123
Total	47			-1.761 (= $\Sigma p_i \ln p_i$)
H				$-1 \bullet \Sigma p_i \ln p_i = 1.761$

So, the diversity index H = 1.761.

Learning Procedure

1.To prepare for this lesson:

(a) Review the following essays:

Chemosynthetic Communities in the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/02mexico/background/communities/communities.html); and

The Ecology of Gulf of Mexico Deep-Sea Hardground Communities (http://oceanexplorer.noaa.gov/explorations/06mexico/background/hardgrounds/hardgrounds.html).

(b) You may also want to review the following visual resources and consider presenting some of these to your students:

- Image collections from Sulak, *et al.* (2008). Master Appendix D of this large report contains many images of deep-water coral communities. Download the pdf files "Master Appendix D - Megafaunal Invertebrates of Viosca Knoll, *Lophelia* Community Investigation," and "Key to Plates in Master Appendix D" from http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

- Video showing some of the extraordinary biological diversity of the Gulf of Mexico (http://oceanexplorer.noaa.gov/explorations/03mex/logs/summary/media/ngom_biodiversity_cm3.html)

- Videos of deepwater corals and coral communities (http://oceanexplorer.noaa.gov/explorations/09lophelia/logs/photolog/photolog.html)

- Virtual tour of a cold-seep community (http://www.bio.psu.edu/cold_seeps)

- Slideshow of highlights from Expedition to the Deep Slope 2006 (http://oceanexplorer.noaa.gov/explorations/06mexico/background/media/slideshow/slideshow.html)

- Slideshow of images from the Expedition to the Deep Slope 2007 (http://oceanexplorer.noaa.gov/explorations/07mexico/logs/summary/media/slideshow/html_slideshow.html)

2. Lead a discussion of deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis. In both processes, organisms build sugars from carbon dioxide and water. This process requires energy; photosynthesizers obtain this energy from the sun, while chemosynthesizers obtain energy from chemical reactions. Point out that there are a variety of chemical reactions that can provide this kind of energy. Contrast hydrothermal vent communities with cold-seep communities.

   Discuss the importance of the Gulf of Mexico to U.S. petroleum resources, as well as the potential importance of deep-sea biological communities that might be adversely affected by exploration and development of petroleum resources. Ask students to brainstorm steps that might be taken to avoid adverse impacts. Tell students that one of the ways scientists describe and compare biological communities is based on the concept of biological diversity, also called biodiversity.

   Discuss this concept. Show students the sample data given in the Background Information section and ask them which of the two communities they intuitively feel is most diverse. This should lead to the concepts of species richness and evenness. Say that the Shannon-Weaver information function is a commonly-used index of diversity that incorporates both concepts of species richness and evenness. Work through the sample calculation, and be sure students understand the steps involved.

3. Tell students that expeditions to deep-sea communities often discover new and unusual communities of living organisms, and that calculations of diversity indices provide a way to compare various communities. Distribute copies of *Species Distribution in Seep and Non-Seep Areas at Two Sites on the California Slope* to each student group. Tell students that they are to calculate the Shannon-Weaver diversity index for each of the four communities included in the sample, and to use this index to compare the biodiversity of seep and non-seep communities at the two sites (A and B). You may want to divide the assignment among the student groups (each group calculating the diversity index for one or two communities). You may also want to suggest that students use a spreadsheet program to speed the calculation process. One approach is to set up columns in the spreadsheet to make the calculations described in the sample diversity index calculation in Background Information, then enter the species data for the appropriate communities.

4. Have student groups summarize their results on an overhead transparency, or a marker board. This summary should resemble Table 3.

Table 3

	Site A		Site B	
	Non-Seep Area	**Seep Area**	**Non-Seep Area**	**Seep Area**
Diversity Index H	1.56	0.57	1.46	1.43

Have each student write an individual analysis of these results. Lead a group discussion of these results. Students should realize that the diversity of seep and non-seep communities differed considerably at Site A, with the seep site having the lower diversity index. Point out that even though the total number of individuals at the seep site was greater than at the non-seep site, the seep site was heavily dominated by one species (*Mediomastus* spp.); consequently, the diversity index was lower. In contrast, there was little difference in diversity between the seep and non-seep communities at Site B. Ask students to speculate on the possible reasons for these results. The investigators who gathered these data concluded that the seep areas sampled were relatively small and possibly transient, and that the fauna in these communities were not highly adapted to or dependent upon the methane-seep environment. Conditions may have been more severe at the seep area in Site A, excluding some species that were found in the surrounding non-seep environment.

Lead a discussion on the significance of biodiversity. The fact that diversity often decreases in stressed environments suggests that high diversity may be "good." On the other hand, it is important to realize that diversity can also be increased by changed or variable conditions (such as those at the boundary of two different types of habitat) or following a major change in a mature ecosystem (such as a forest fire). Encourage pro and con discussion of these questions, but be sure to challenge students to defend their positions. At some point in this discussion, ask students whether "unknown" is the same as "unimportant." You may want to cite examples in which obscure species proved to be directly important to humans (such as the Madagascar periwinkle that provides a powerful cancer treatment).

The Bridge Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Habitats," then "Deep Sea" for resources on deep-sea communities.

The "Me" Connection

Have students write a short essay contrasting and comparing the importance of diversity in ocean communities to their own communities.

Connections to Other Subjects

English/Language Arts, Earth Science, Mathematics

Assessment

Written and oral group reports provide opportunities for assessment.

Extensions

See the "Resources" section of *Lessons from the Deep: Exploring the Gulf of Mexico's Deep-Sea Ecosystem Education Materials Collection Educators' Guide* for additional information, activities, and media resources about deepwater ecosystems in the Gulf of Mexico.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 3, 5, and 6 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

From the Gulf of Mexico to the Moons of Jupiter (6 pages, 207 KB)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_moons.pdf

Focus - Adaptations to unique or "extreme" environments (Earth Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and will be able to compare physical conditions in deep-sea "extreme" environments to conditions thought to exist on selected moons of Jupiter. Students will also discuss the relevance of chemosynthetic processes in cold seep communities to the possibility of life on other planetary bodies.

Biochemistry Detectives (8 pages, 480 K)

http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_biochem.pdf

Focus - Biochemical clues to energy-obtaining strategies (Chemistry)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three energy-obtaining strategies used by organisms in cold-seep communities. Students will also be able to interpret analyses of enzyme activity and ^{13}C isotope values to draw inferences about energy-obtaining strategies used by organisms in cold-seep communities.

This Old Tubeworm (10 pages, 484 KB)

http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus - Growth rate and age of species in cold-seep communities (Life Science)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals *of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age specific growth in individuals of the same species.*

C.S.I. on the Deep Reef (Chemotrophic Species Investigations, That Is) (6 pages, 444 KB)

http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/gom_06_csi.pdf

Focus: Chemotrophic organisms (Life Science/Chemistry)

In this activity, students will describe at least three chemotrophic symbioses known from deep-sea habitats and will identify and explain at least three indicators of chemotrophic nutrition.

Gellin (4 pages, 372 KB)

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_gellin.pdf

Focus - DNA analysis (Life Science)

In this activity, students will explain and carry out a simple process for separating DNA from tissue samples, explain and carry out a simple process for separating complex mixtures, and explain the process of restriction enzyme analysis.

Hot Food (4 pages, 372 KB)

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_hotfood.pdf

Focus - Energy content of hydrocarbon substrates in chemosynthesis (Chemistry)

In this activity, students will compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities, and given information on the molecular structure of two or more substances, will make inferences about the relative amount of energy that could be provided by the substances. Students will also be able to make inferences about the potential of light hydrocarbons as an energy source for deep-water coral reef communities.

How Does Your (Coral) Garden Grow? (6 pages, 456 KB)

http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_growth.pdf

Focus - Growth rate estimates based on isotope ratios (Life Science/Chemistry)

In this activity, students will identify and briefly explain two methods for estimating the age of hard corals, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals.

What's the Difference? (20 pages, 300 kb)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/difference.pdf
Focus - Identification of biological communities from survey data (Life Science)
In this activity, students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

Other Links and Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/ – Ocean Explorer Web site

Levin, Lisa A., David W. James, Christopher M. Martin, Anthony E. Rathburn, Leslie H. Harris, Robert H. Michener 2000. Do methane seeps support distinct macrofauna assemblages? Observations on community structure and nutrition from the northern California slope and shelf. Marine Ecology Progress Series 208:21-39. Available online at levin.ucsd.edu/publications/SEEPMEPS208.pdf

Kellogg, C.A., 2009, Gulf of Mexico deep-sea coral ecosystem studies, 2008–2011: U.S. Geological Survey Fact Sheet 2009– 3094, 4 p.

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://diffeomorphism.com/~carrie/courses/BIOL_309/deepseacorals.pdf

Sulak, K. J., M. T. Randall, K. E. Luke, A. D. Norem, and J. M. Miller (Eds.). 2008. Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral - *Lophelia* Reef Megafaunal Community Structure, Biotopes, Genetics, Microbial Ecology, and Geology. USGS Open-File Report 2008-1148; http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

Fisher, C., H. Roberts, E. Cordes, and B. Bernard. 2007. Cold seeps and associated communities of the Gulf of Mexico. Oceanography 20:118-129; available online at http://www.tos.org/oceanography/issues/issue_archive/20_4.html

http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/maincontent.htm – Web site for the National Methane Hydrate Research and Development Program

http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html – Gas (Methane) Hydrates—A New Frontier; Web page from the U.S. Geological Survey's Marine and Coastal Geology Program

Van Dover, C.L., P. Aharon, J.M. Bernhard, E. Caylord, M. Doerriesa, W. Flickinger, W. Gilhooly, S.K. Goffredi, K.E. Knick, S.A. Macko, S. Rapoport, E.C. Raulfs, C. Ruppel, J.L. Salerno, R.D. Seitz, B.K. Sen Gupta, T. Shank, M. Turnipseed, R. Vrijenhoek. 2003. Blake Ridge methane seeps: characterization of a soft-sediment, chemosynthetically-based ecosystem. Deep-Sea Research Part I 50:281–300. (Available as a PDF file at http://www.mbari.org/staff/vrijen/PDFS/VanDover_2003DSR.pdf)

MacDonald, I. and S. Joye. 1997. Lair of the "Ice Worm." Quarterdeck 5(3); http://www-ocean.tamu.edu/Quarterdeck/QD5.3/macdonald.html; article on cold-seep communities and ice worms

Siegel, L. J. 2001. Café Methane. http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=86; article on cold-seep communities and ice worms from NASA's Astrobiology Institute

Kirschvink, J. L. and T. D. Raub. 2003. A methane fuse for the Cambrian explosion: carbon cycles and true polar wander. Comptes Rendus Geoscience 335:65-78. Journal article on the possible role of methane release in rapid diversification of animal groups. Also available on-line at http://www.gps.caltech.edu/users/jkirschvink/pdfs/KirschvinkRaubComptesRendus.pdf

Simpson, S. 2000. Methane fever. *Scientific American* (Feb. 2000) pp 24-27. Article about the role of methane release in the Paleocene extinction event

http://www.piersystem.com/go/site/2931/ – Main Unified Command Deepwater Horizon response site

http://response.restoration.noaa.gov/deepwaterhorizon – NOAA Web site on Deepwater Horizon Oil Spill Response

http://docs.lib.noaa.gov/noaa_documents/NESDIS/NODC/LISD/Central_Library/current_references/current_references_2010_2.pdf – Resources on Oil Spills, Response, and Restoration: a Selected Bibliography; document from NOAA Central Library to aid those seeking information concerning the Deepwater Horizon oil spill disaster in the Gulf of Mexico and information on previous

spills and associated remedial actions; includes media products (Web, video, printed and online documents) selected from resources available via the online NOAA Library and Information Network Catalog (NOAALINC)

http://www.gulfallianceeducation.org/ – Extensive list of publications and other resources from the Gulf of Mexico Alliance; click "Gulf States Information & Contacts for BP Oil Spill" to download the Word document

http://rucool.marine.rutgers.edu/deepwater/ – Deepwater Horizon Oil Spill Portal from the Integrated Ocean Observing System at Rutgers University

http://www.darrp.noaa.gov/southeast/deepwater_horizon/ index.html – Information about damage assessments being conducted by NOAA's Damage Assessment Remediation and Restoration Program

http://response.restoration.noaa.gov/ – Click "Students and Teachers" in the column on the left for information, fact sheets, and activities about oil emergencies, habitats, and other ocean issues

http://www.noaa.gov/sciencemissions/bpoilspill.html – Web page with links to NOAA Science Missions & Data relevant to the Deepwater Horizon/BP Oil Spill

http://ecowatch.ncddc.noaa.gov/jag/data.html – Data Links page on the Deepwater Horizon Oil Spill Joint Analysis Group Web site

http://ecowatch.ncddc.noaa.gov/jag/reports.html – Reports page on the Deepwater Horizon Oil Spill Joint Analysis Group Web site

http://www.education.noaa.gov/Ocean_and_Coasts/Oil_Spill.html - "Gulf Oil Spill" Web page from NOAA Office of Education with links to multimedia resources, lessons & activities, data, and background information

http://www.geoplatform.gov/gulfresponse/ - Web page for GeoPlatform.gov/gulfresponse—an online map-based tool developed by NOAA with the EPA, U.S. Coast Guard, and the Department of Interior to provide a "one-stop shop" for spill response information; includes oil spill trajectory, fishery area closures, wildlife data, locations of oiled shoreline and positions of deployed research ships

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Interactions of energy and matter

Content Standard C: Life Science

- Interdependence of organisms

Content Standard D: Earth and Space Science

- Geochemical cycles

Content Standard F: Science in Personal and Social Perspectives

- Environmental quality

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 4.
The ocean makes Earth habitable.

Fundamental Concept b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean

support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.
Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please e-mail your comments to: oceanexeducation@noaa.gov

For More Information

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Species Distribution in Seep and Non-Seep Areas at Two Sites on the California Slope

(condensed from Levin, *et al*., 2000)

Species	Site A		Site B	
	Non-Seep Area Total Individuals	Seep Area Total Individuals	Non-Seep Area Total Individuals	Seep Area Total Individuals
Cnidaria				
Obelia sp.	0	2	0	0
Anemone	0	0	6	0
Scolanthus sp.	0	1	0	0
Edwardsid sp.	3	0	0	0
Platyhelminthes				
Turbellaria	0	0	1	0
Polycladida	0	1	0	0
Nemertea				
Unidentified nemertean	1	4	1	1
Cerebratulus sp.	1	0	1	0
Lineus bilineatus	0	1	0	0
Annelida				
Amaeana occidentalis	6	200	8	0
Ampharete arctica	1	0	1	0
Apoprionospio pygmaea	0	0	7	4
Aricidea catherinae	1	4	2	0
Chaetozone cf. *hartmanae*	300	0	0	0
Chaetozone columbiana	0	120	0	0
Eteone cf. *spilotus*	3	0	1	0
Glycera cf. *convoluta*	0	0	3	0
Glycinde sp.	1	2	0	0
Heteromastus filobranchus	150	180	0	0
Levinsenia oculata	0	1	0	0
Magelona sp.	0	1	0	0
Mediomastus spp.	0	10200	0	1
Myriochele sp.	1	0	0	0
Orbinia johnsoni	0	0	1	0
Pholoe glabra	2	5	0	0
Prionospio (Minuspio) lighti	3	140	3	0
Proceraea sp.	0	1	0	0
Scoletoma tetraura	200	190	220	1
Spiochaetopterus costarum	0	1	0	0
Sternaspis fossor	6	7	0	0